Intel response to the Consultation Paper Issued by the Info-Communications Media Development (IMDA) Authority of Singapore on 5G Mobile Services and Networks

4) IMDA would like to seek views and comments on whether going forward, there is a need for further spectrum below 1 GHz to be identified and release for mobile services?

As available spectrum resources are taxed to their limits, meeting the data challenge of 5G will require the industry to explore new ways to optimize current spectrum usage, utilize newly-licensed frequency ranges, and tap into new and existing license-exempt bands. This is increasingly important as we witness deployment of technologies that support a variety of 5G devices and use cases, for example, enabling higher bands in support of enhanced Mobile Broadband (eMBB) but also enabling <1 GHz bands to support IoT and applications requiring longer range and/or greater building penetration.
Propagation characteristics of frequencies below 1 GHz are such that they enable longer range (coverage) and obstacle penetration. These characteristics would help facilitate economic deployment of certain 5G applications such as massive sensor networks, e.g. in the context of smart cities, as well as coverage for underserved and/or remote areas.

Additionally, it's important—to the extent practical--to align spectrum frequency ranges that can be harmonized across leading geographies in order to deliver economies of scale for manufacturers and operators, accelerating the delivery of 5G products and services. In this regard, it is important to continue the work in the Asia-Pacific region to enable IMT in bands below 700 MHz as are underway in Bangladesh, India, Maldives, Micronesia, New Zealand, Pakistan, the Solomon Islands, Tuvalu and Vanuatu[1]. One example of how part of the sub-700 MHz band could be made available for IMT is the recently concluded US incentive auction[2].

5) IMDA would like to seek views and comments on following:

i) The frequency arrangement that is better suited for adoption in Singapore for the L band (i.e. SDL, TDD or FDD) and the supporting reasons; and

ii) The timeline for access to the L band and the availability of the equipment (specifically whether it will be available earlier or later than 2020).

Based on regulatory work for the L-band in other regions, Intel believes that an SDL frequency arrangement is the best solution for Singapore. CEPT has already decided on this implementation last year and we see similar trends in the Americas. Whilst we recognize that the discussion at ITU level is still ongoing and certain countries might prefer TDD or FDD for reasons specific to their local situation such as legacy systems, we are of the view that the broadest economies of scale and earliest equipment availability for the L-band will be achieved with SDL globally.

8) Considering the challenges of co-channel deployment of FSS and IMT services in the extended C-band, IMDA would like to seek views and comments on the coexistence measures for adjacent bands and cross border operations.

[1] See GSMA paper „600 MHz for mobile broadband – Momentum is growing" (https://www.gsma.com/spectrum/wp-content/uploads/2017/06/600MHz-for-mobile-broadband.pdf)
[2] See FCC information at https://www.fcc.gov/wireless/auction-1000

Coexistence of FSS and IMT has been analyzed in great detail in various fora. Examples include Report ITU-R M.2368. Further information on this issue has been put together by the GSMA[3]. In addition, CEPT has published ECC-Report 254[4] "Operational guidelines for spectrum sharing to support the implementation of the current ECC framework in the 3600-3800 MHz range" in order to facilitate the use of the full 3400-3800 MHz band for IMT as set out in the CEPT Roadmap for 5G.[5]

Considering these studies, it is obvious that a range of coexistence conditions are presented, which point to the fact that a theoretical sharing study is only as good as the assumptions used for the study. Therefore, choosing realistic assumptions on parameters and modeling of either system, including the right protection criteria, is of utmost importance.

Based on our analyses, Intel is of the view that utilizing realistic assumptions for the FSS and IMT systems points to opportunities for sharing. These realistic assumptions include:

- Realistic FSS parameters in line with those of real satellite systems as registered with the ITU-R
- Appropriate propagation models commensurate with the analyzed scenarios
- Correct modeling of the IMT system as a network (i.e. based on Recommendation ITU-R M.2101)
- Technically sound protection criteria based on a C/(I+N) analysis that captures the real performance of a victim receiver, as opposed to a fixed I/N value which does not convey any information on the actual performance of the victim receiver in presence of external interference
- Power Flux Density (pfd) values based on realistic system parameters for cross-border situations

The coexistence analyses could also take advantage of mitigation techniques that could facilitate coexistence even more. Two of the most effective mitigation techniques are exclusion zones around victim receivers (for co-frequency sharing) and adequate guard bands between the two systems, for cases where the band could be segmented between the two systems. Other mitigation techniques also exist including using Advanced Antenna Systems (AAS), which, where appropriate, could enable beam- and null-steering that reduce interference and facilitate sharing.

10) IMDA would like to seek your views and comments on the following:
i) The role mmWave bands will play in delivering the vision of 5G, in particular, what services could not be delivered by alternative frequency bands and / or technologies;

Intel believes that while the technology developments for these bands are in the relatively early stages, millimeter wave frequencies are technically feasible for mobile applications, including the use for providing enhanced Mobile Broadband (eMBB) applications such as 4k/8k video streaming and AR/VR[6], peak period congestion relief in densely populated locations, connected homes and cars, as well as M2M/IoT (Machine to machine /Internet of Things) applications. The need for higher peak data rates, more bandwidth (especially during the busiest hour, which is growing faster than the average hour), reduced latency, and higher sustained throughput are some of the key drivers for the next generation

[3] See GSMA papers „Considerations for the 3.5 GHz IMT range: getting ready for use" (https://www.gsma.com/spectrum/wp-content/uploads/2017/06/Considerations-for-the-3.5-GHz-IMT-range-v2.pdf) and „Fair FSS Sharing - Safeguarding mobile growth" (https://www.gsma.com/spectrum/wp-content/uploads/2017/06/Fair-FSS-sharing.pdf)
[4] http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCREP254.PDF
[5] https://cept.org/ecc/topics/spectrum-for-wireless-broadband-5g
[6] Augmented Reality/Virtual Reality

wireless access networks in mmWave bands. Intel has provided long-standing support for service and technology flexibility in the rules created for new spectrum allocations, and these mmWave bands are no different. IMDA should strive to provide such flexibility and incentives to maximize the value of the spectrum, subject to minimal regulatory constraints.

ii) The amount of spectrum required in the mmWave spectrum bands to meet 5G applications that will require higher bandwidths; and

Intel believes that channel bandwidth in the range of 100MHz (minimum) or higher in spectrum blocks up to 2 to 3 GHz, where feasible, is needed to achieve the service requirements of 5G users (data rates on the order of 100 Mbit/s to 1 Gbit/s for cell edge and 10 to 20 Gbit/s as peak rates for fast download of rich content, real-time video streaming, cloud services, etc.). Multiple such channels will be needed, and channel partitioning and aggregation should be permitted in order to adjust to market demand for different application loading needs. Spectrum blocks should also be able to accommodate multiple operators to encourage competition and foster subscriber growth.

ITU-R has performed a study on spectrum needs of IMT in bands above 24 GHz. According to ITU-R study, based on the range of the assumptions, a corresponding range of spectrum needs are being presented that span from several hundred MHz to several GHz of spectrum would be needed to meet IMT-2020's key technical performance requirements such as peak data rate, average user data rate, latency, etc.

WiGig devices are emerging examples of 802.11ad commercial systems operating in the mmWave bands that establish the viability of short range mmWave operation. WiGig provides the example of a wideband system (i.e. 2.16 GHz bandwidth) deploying antenna arrays, power amplifiers, low noise amplifiers etc., operating in the 60GHz band. Given this established operation at 60GHz, and the broad similarity of expected modes of operation across the mmWave spectrum, we anticipate that the same underlying technologies can be re-applied at frequencies between 24GHz and 95GHz, supporting a wide-variety of operational bandwidths from 100MHz to over 2 GHz depending on the frequency band, the varying bandwidth needs for different applications, and mode of deployment.

iii) The specific mmWave bands that you consider should be a priority in Singapore for IMT services and why?

Intel commends IMDA for exploring the use of spectrum in the mmWave band. Intel believes both licensed and license-exempt allocations above 24 GHz have potential value for future mobile communications use. Given the state of development of products for upcoming trials and commercial deployments around the world as well as 3GPP standardization, Intel recommends adoption of all or parts of the following bands as immediate candidate bands for such use: The 28 GHz range (26.5-29.5 GHz), the 26 GHz band (24.25-27.5 GHz) the 40 GHz range (all or parts of 37-43.5 GHz) for licensed use, and the 66-71 GHz range for license-exempt use (extending the current 57-66 GHz range as defined by the ITU).

As part of the WRC-19 preparation process, the ITU-R is expected to complete relevant sharing and coexistence studies by mid-2018. Therefore, there is a need to expeditiously assess the viability of these bands in advance of that processes. There are technology development, cost, and scale benefits to global harmonization, and IMDA's expeditious consideration, analysis, and conclusions on mmWave bands could influence the harmonization process and the outcomes of the ITU-R and WRC-19 processes. It

should be noted that several administrations have already initiated consultations on candidate mmWave bands, or in the case of the U.S., have already allocated mmWave bands for future mobile communications use, and as a result a framework for global harmonization has already been initiated.

11) Considering that there are 11 candidate bands under consideration at WRC-19, how would making available the 28 GHz band help in the deployment of 5G services in Singapore? Would this band play a significant role in achieving the targets set out for 5G (i.e. higher throughput, ultra-low latency)?

Intel believes that making the 28 GHz band (the larger range of spectrum generally considered between 26.5 and 29.5 GHz) available will be a significant step forward in the deployment of 5G services in Singapore and would enable Singapore to be at the forefront of 5G deployments together with other innovative early-adopter markets in the Asia-Pacific and North American regions.

We believe that the emerging deployment technologies applicable to mmWave bands, and specifically the 28 GHz band, could support a variety of use cases and therefore deployment models, including, for example deployments where:

- 28 GHz small cells provide very high speed "booster" capability that is closely coupled to, and augment, existing wide-area data networks such as 3G and 4G networks;
- 28 GHz backhaul providing in-band or out-of-band access from network associated small cells operating to support 3G and 4G access and core networks;
- 28 GHz access points operating on a stand-alone basis to provide very high speed data services in enterprises, public transportation centers etc. In such examples, associated IT infrastructure would provide network control, and
- 28 GHz access points operating on a stand-alone basis to provide very high speed, low latency machine control for Internet of Things applications in manufacturing, automotive, etc..

As stated by IMDA in the consultation document, all of 5G trials and pre-commercial tests (e.g. USA, Korea, and Japan) are currently taking place in the 28 GHz band as this is the first band for which the ecosystem for 5G equipment is currently developing products for due to early-mover countries opening up this band for 5G. In addition, this band is in the range with most support in 3GPP for early New Radio (NR) specification development in bands above 6 GHz. In our view, the 28 GHz band is enjoying a de facto harmonization across regions due to the early-mover actions by certain administrations. Therefore, making the 28 GHz band available for 5G deployment would enable Singapore to benefit from this early ecosystem development and trial/launch possibilities to help achieving the targets set out for 5G for commercial deployments by 2020. Other bands under consideration at WRC-19 are facing some level of uncertainty due to possible restriction added to their use by WRC-19, which impact product availability, or they may not be identified for IMT by WRC-19.

12) If the 28 GHz band is opened for IMT services in Singapore, would there be any future competing services that may be deployed in this band which may cause interference issues?

The 28 GHz band is under study for Earth Stations in Motion (ESIM) under WRC-19 Agenda Item 1.5 and technical conditions for such use will be developed by ITU to ensure protection of, and not impose undue constraints on, services allocated in this frequency band, i.e. the Fixed and the Mobile service. One such condition was already agreed by WRC-15 for ESIM operation in the adjacent 29.5-30.0 GHz band which, according to Resolution 156 (WRC-15), states that ESIM, with respect to any terrestrial

systems operating in the bands, shall not claim protection or impose constraints on the development of these services.

As stated by IMDA in the consultation document, such usage is restricted to only 28.6 – 29.1 GHz in Singapore and the band is currently under-utilized with uplink transmissions mostly confined to air platforms or vessels, restricted to certain technical parameters such as emission power and minimum operating elevation angle. It will be important to implement the conditions as developed for WRC-19 in order to ensure the protection of the use of the 28 GHz band by 5G terrestrial systems and by doing so avoid interference to 5G.

Our preliminary studies reveal that interference generated by introduction of ESIM in adjacent band to Mobile in the 28 GHz band may or may not reach harmful levels depending on the ESIM deployment scenario and the distances and environments involved. For instance, operation of ESIM on vessels out at sea would create a different situation compared to operation on vessels while docked at a port. Similarly, operation of ESIM on aerial platforms, e.g. airplanes, while in the air would create a very different situation from the case where they are parked at a gate in an airport.

14) Noting that several regulators have made available mmWave bands for IMT services, IMDA would like your views and comments on whether access to the mmWave spectrum should be provided earlier than 2022 for commercial network deployment?

In short, yes, the mmWave bands such as the 28 GHz band should be made available earlier than 2022, and IMDA's expeditious consideration, designation, and assignment of mmWave bands could influence the harmonization process and the outcomes of the ITU-R and WRC-19 processes.

Intel believes global harmonization efforts will enhance economies of scale and provide products that could roam globally. Operation on such global scale would reduce cost to consumers while at the same time promote innovation through opening global markets. It should be noted that even though progress has been made in recent years on digitalization of RF subsystems and components leading to increasing number of radios in mobile devices, form factor constraints limits such increase through cost/performance trade-offs. As a result, it is important that mmWave bands considered by the IMDA both have the potential for being globally harmonized and are made available as soon as is feasible.

In this regard, consideration of similar developments around the world is essential in making a prudent decision. In particular, Intel would like to draw IMDA's attention to the concept of RF tuning ranges whereby the adjacency of range of frequencies bands are taken into consideration even though only a part of the larger range could be made available in a given country. For instance, the United States has allocated 27.5-28.35 GHz for 5G services, whereas Korea is considering 26.5-29.5 GHz, and Europe is considering 24.25-27.5 GHz. Therefore, equipment manufacturers could take advantage of the overlap of these bands to stage their development of RF components for the larger tuning range in due time and create economies of scale for a de facto global range.

15) Considering the current regulations/policies for license-exempt use and the possibility of LTE-U interfering with Wi-Fi users, IMDA would like to seek views and comments on the following:

i) The adoption of LBT to facilitate sharing of license-exempt spectrum and whether there would be any implication arising from such a requirement;

ii) The need for further technical requirements and regulatory measures to facilitate the sharing of license-exempt spectrum in an efficient and fair manner; and

iii) The need for companies with commercial LTE-U networks to upgrade to LAA once the software/hardware products are commercially available.

Intel considers the following technical aspects to be critical for fair coexistence of collocated LAA and Wi-Fi networks:

- Listen Before Talk (LBT) channel access mechanism with adaptive back off and a contention window that is compatible with 802.11
- Appropriate Clear Channel Assessment level and smart channel selection
- Maximum transmission duration which does not impact voice and video services over Wi-Fi
- Mitigation mechanisms for the hidden node problem

Intel is concerned that the LAA / LTE-U specification may mandate use of LBT only where regulations require it, which could be detrimental to existing Wi-Fi deployments. It is our understanding that pre-standard LTE-U does not employ LBT, though it does limit maximum transmission duration, which raises concerns with respect to Wi-Fi coexistence.

In order to address or at least mitigate the concerns raised regarding the LTE-U sharing of licensed-exempt spectrum with Wi-Fi, Wi-Fi Alliance and LTE-U manufacturers have developed a co-existence test plan that is published and available for public access.[7]. In order to promote fair co-existence between technologies, Intel recommends IMDA to require that devices satisfy the Wi-Fi Alliance LTE-U Coexistence Test Plan.

LAA requires an anchor channel in the licensed spectrum, which essentially allows LTE traffic to travel within the license-exempt band via a secondary cell, using carrier aggregation to bring the two data streams together in the downlink. In Rel. 14, LAA is specified to also support traffic on the uplink. LAA/eLAA utilizes a Listen-Before Talk (LBT) transmission protocol in order to prevent interference and ensure coexistence between LTE and Wi-Fi devices. LAA, as a global standard, is also likely to have a larger ecosystem of equipment, both on the infrastructure and client when comparing with the proprietary LTE-U technology.

Regarding the LAA sharing of license-exempt spectrum, Intel believes that support of no single feature will effectively and fairly address the co-existence in the band on its own. Therefore, Intel recommends that IMDA to consider development of an industry lead co-existence test plan for LAA/eLAA and Wi-Fi similar to that developed by Wi-Fi alliance for LTE-U and establishment of testing program.

16) During the interim period before regulations are finalised, IMDA plans to facilitate industry trials for LAA/LTE-U technologies. As such IMDA would like to seek views and comments on the following:

i) Besides the information listed in Para 80, should MNOs/MVNOs interested in conducting LTE-U trials submit any further information for IMDA's assessment; and

ii) To minimise impact to Wi-Fi users, should IMDA limit LAA/LTE-U trials to parts of the 5 GHz licence-exempt spectrum?

[7] Wi-Fi Alliance, Wi-Fi Alliance® Delivers LTE-U Coexistence Test Plan, Sept. 21, 2016, available at http://www.wi-fi.org/news-events/newsroom/wi-fi-alliance-delivers-lte-u-coexistence-test-plan

For trial purposes only, IMDA should confine deployments where Wi-Fi is dense and there are a variety of applications implemented. The limitation to parts of the 5 GHz band should only be in the context of trial work – not for commercial deployments.

As stated in the answer to Question 15, Intel recommend IMDA requiring that devices comply with the test protocol that Wi-Fi Alliance has developed to promote fair coexistence in conjunction with trial activities.

17) IMDA would like to seek views and comments on the following:

i) The possibility of deploying LAA and / or MuLTEfire in other frequency bands besides the licence-exempt 5 GHz band; and

ii) The regulatory and coexistence measures that should be adopted for MuLTEfire.

MulteFire technology is working on implementing a control and paging channels in the license-exempt bands (unlike LAA and LWA, which retain control and paging in the licensed "anchor" bands). Control and paging in MulteFire follow the same listen before talk (LBT) mechanism as LAA. Therefore, MulteFire coexists with Wi-Fi in the same way as LAA.

Intel supports 3GPP-endorsed standards-based technologies built for fair coexistence in the license-exempt bands, including eLWA, LWA, LAA and LWIP. Working closely with partners across both industries, Intel is helping define best practices for radio access technologies that leverage license-exempt spectrum. Intel supports the development of industry accepted test plans and certifications that assess the coexistence of technologies operating in license-exempt bands, such as LAA and Wi-Fi. As stated in response to Question 15, Wi-Fi Alliance has an active program in this space. The Wi-Fi Alliance completed the development of LTE-U Co-existence Test Plan and also approached 3GPP for possibility of cooperation for development of similar program for LAA.

18) Considering that the LWA approach would not create coexistence issue with Wi-Fi users, would this approach be better suited for countries with extensive Wi-Fi usage?

LTE-Wi-Fi Link-level Aggregation (LWA) is a radio access technology that allows operators to utilize a combination of licensed operation (LTE) in a variety of ranges and license-exempt operation (Wi-Fi) in the 5GHz band to increase data capacity and speeds. LWA can be deployed fast, with minimal changes to existing networks and devices. Leveraging a dual-connectivity (anchor/booster) framework, LWA simultaneously transmits packets belonging to a single stream independently over LTE and Wi-Fi to the device, using the infrastructure eNB as a decision maker.

The data from the cellular and Wi-Fi links are then aggregated in the downlink to provide better throughput to the device, resulting in performance gains that can top 1Gbps. Because LWA uses both standards as-is, it aims to ensure fair access and coexistence between LTE and Wi-Fi devices. LWA is a 3GPP Rel. 13 technology. Slated for 3GPP Rel. 14, enhanced LTE Wi-Fi Link-level Aggregation (eLWA) will operate in the same manner, leveraging Wi-Fi to offer access to the 60 GHz (WiGig) band for rapid data speeds, as well as data uplink support for new use cases. By tapping into Wi-Fi, which already operates in the mmWave band, eLWA enables the industry to accelerate the delivery of 5G compatible wireless solutions.

Another approach to consider is LTE WLAN Radio Level Integration with IPsec Tunnel (LWIP), which uses an anchor/booster control framework to integrate Wi-Fi in the 3GPP LTE network, coexisting with Wi-Fi

by design, similar to LWA. However, with LWIP, an IP-sec tunnel between the eNB and the terminal device is used to transparently route traffic over Wi-Fi. Because the aggregation is performed at the IP layer (on the handset level), it can be deployed with minimum impact to the existing WLAN infrastructure.

LWIP supports data transmission in both the downlink and uplink, using multiple bearers. Whereas, LWA currently supports downlink transmission, but will soon support (eLWA) uplink as well, using split bearer. This means that, while it cannot offer the same performance gains as LWA or eLWA, LWIP's benefit is that it allows mobile operators to rapidly and cost-effectively address capacity challenges.

19) IMDA would like to seek views on how the above approaches (i.e. LAA, MuLTEfire and LWA) would enhance the capacity of the mobile network in ways that Wi-Fi offloading is not able to achieve.

Wi-Fi Offload and Wi-Fi Roaming services can be supported by the Next Generation Hotspot (NGH) Program based on Passpoint, using 802.1X / EAP authentication / 802.11u standards. These technologies enhance the user experience via an automatic discovery and selection capability which means the user no longer needs to take any steps to connect to the Public Wi-Fi network initially, but rather the device will connect whenever in range of a network supporting its credential.

The Wireless Broadband Alliance (WBA) has been developing, since 2011, wide industry trials and testing between mobile operators, cable operators, ISPs, cities, infrastructure vendors, technology players and device manufacturers. These technologies are today well-understood / mature and are in active deployment globally.

Upcoming technologies like LAA, LWA, and MulteFire are still in an initial phase of development and support in mobile devices will take many years to become widespread.